Appendix D
Session 2

Presentation Charts, Panel Responses, and Questions and Answers

2.0 Technology and Resource Status

2.1 Panel 1: Technology and Industry

2.1.1 Panel Chair:

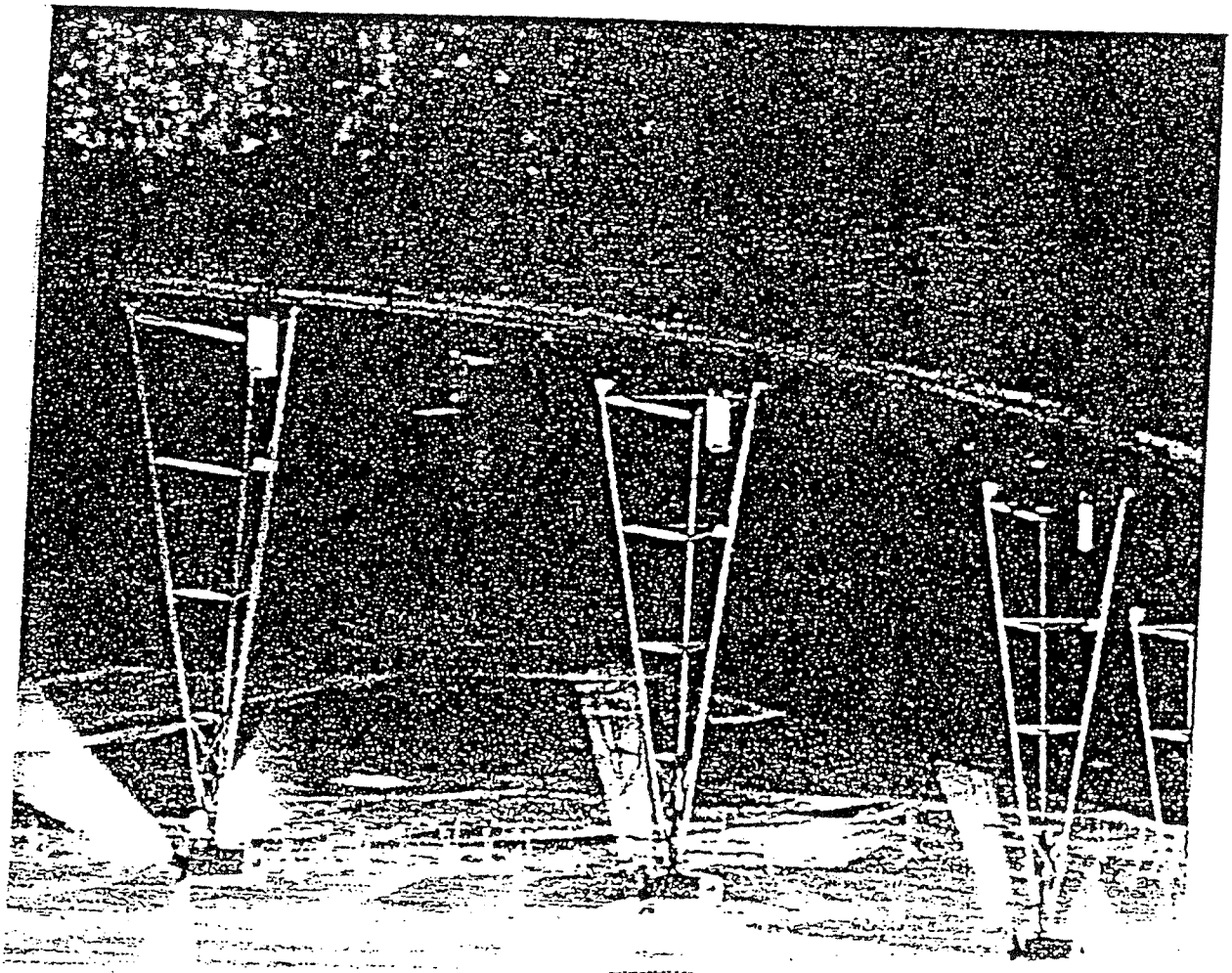
Sue Hock–National Renewable Energy Laboratory (NREL), Golden, CO

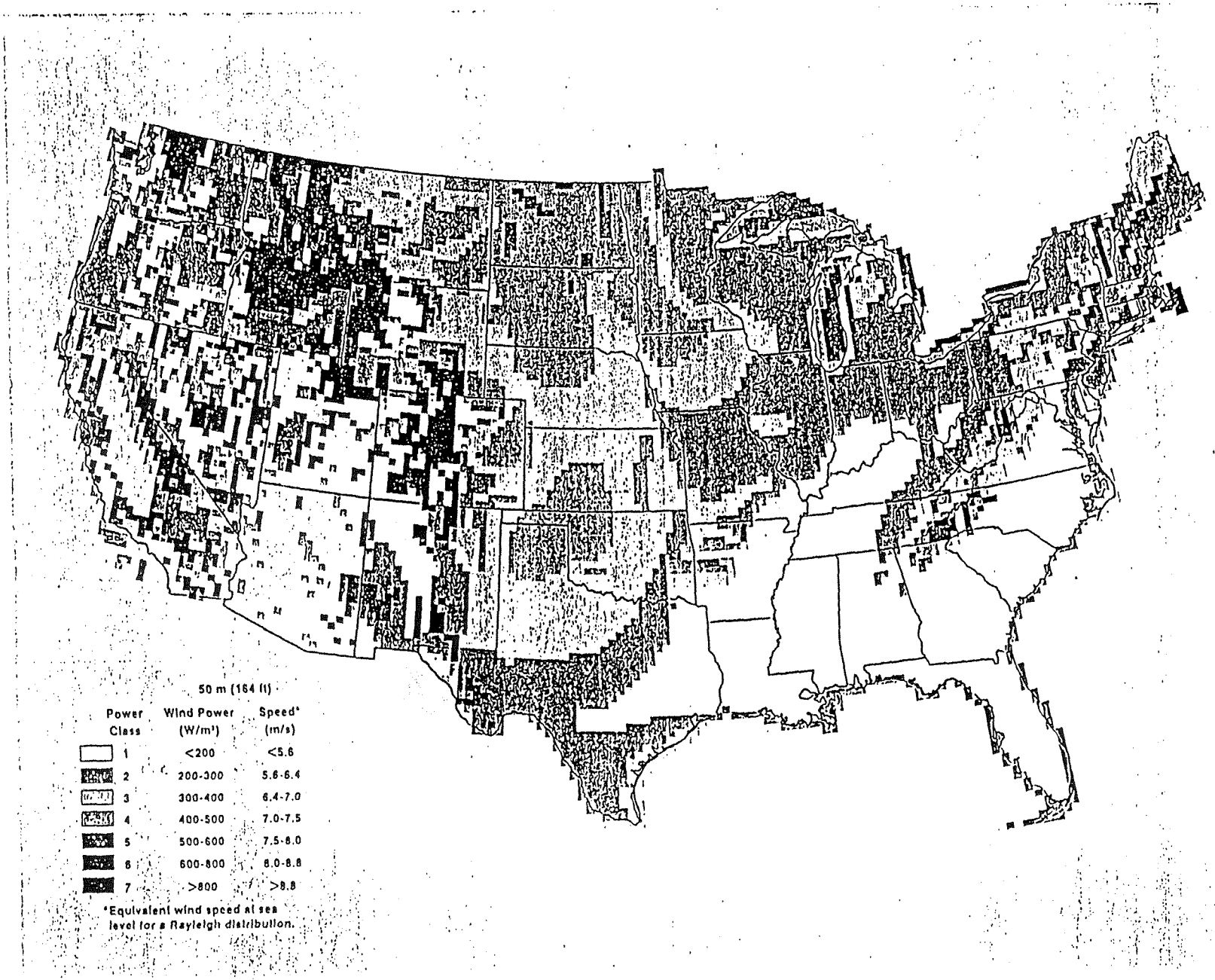
Presentation charts follow

Wind Energy Development: Technology Status and Commercialization

Susan M. Hock, Manager
Wind Energy Program
National Renewable Laboratory
Golden, Colorado

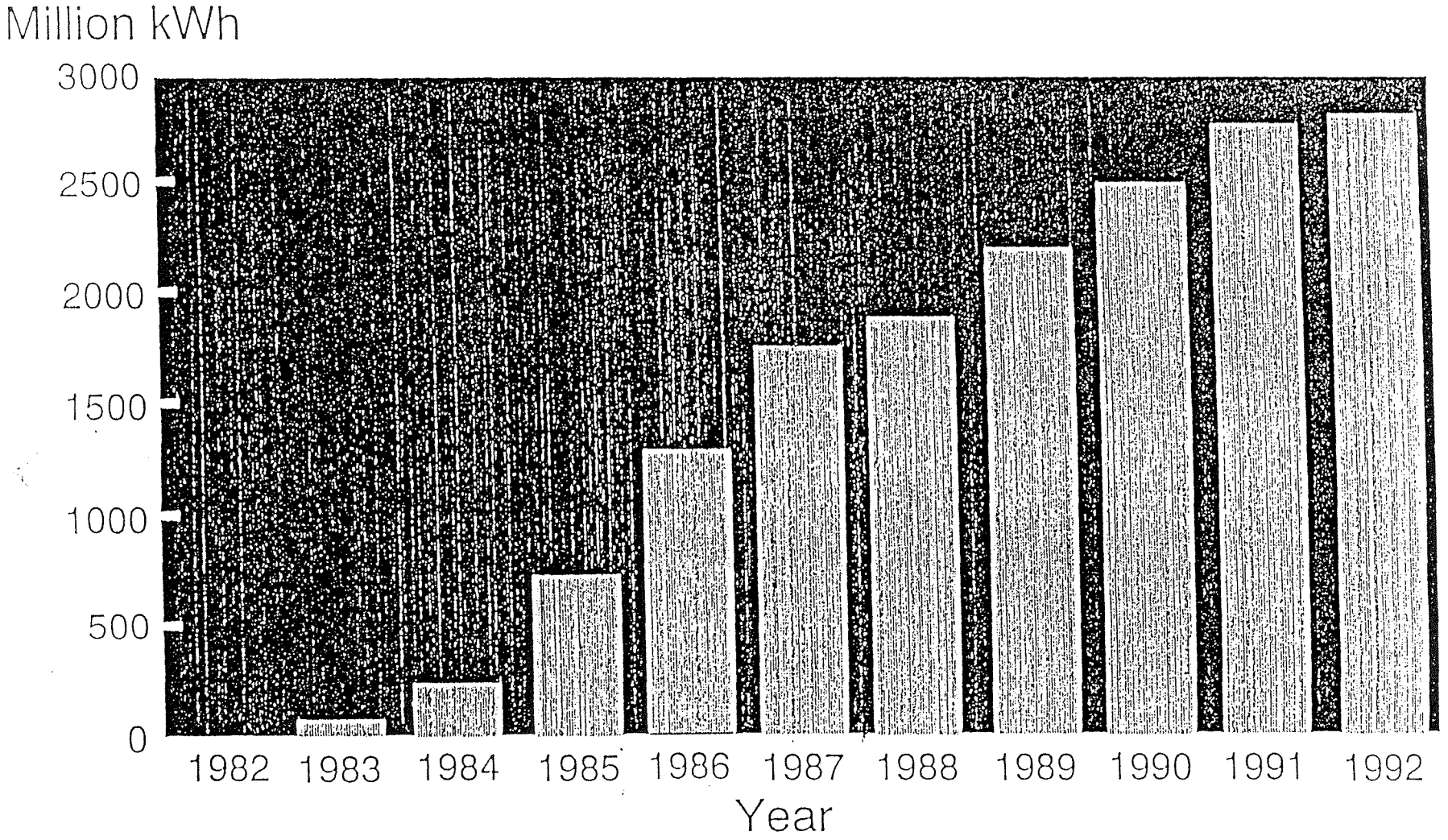
P93-G01004802





Map 2-6 Annual average wind resource estimates in the contiguous United States.

California Wind Power Plants Generation



Sources: CEC, CEC PRS, other 1990 Paul Gipe and Assoc.

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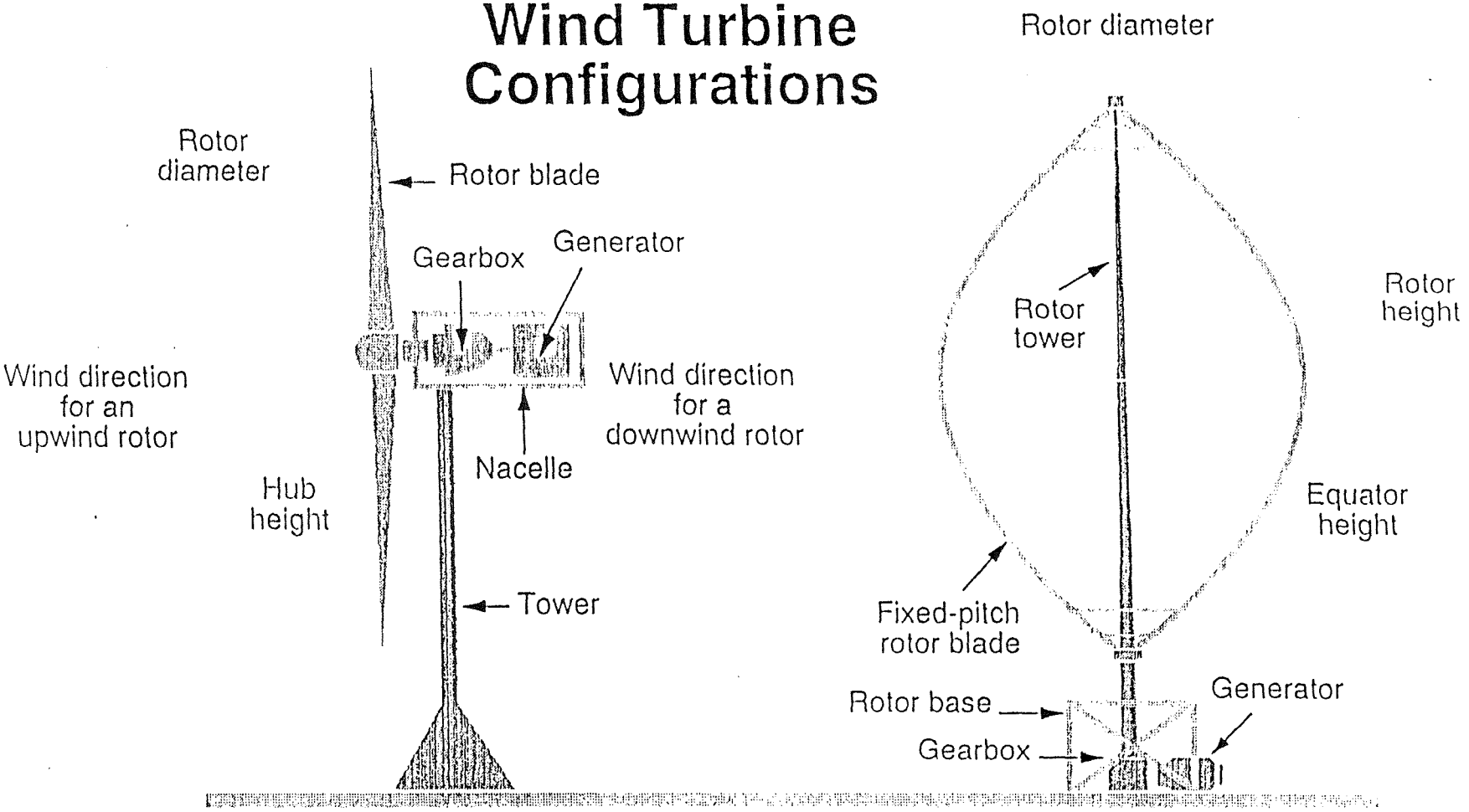
Wind Turbine Configurations



Horizontal-Axis Wind Turbine (HAWT)

Vertical-Axis Wind Turbine (VAWT)

P05-G0943029

Advanced Turbine Development Program

Current Technology – 1989 Baseline

- Commercial machines
- COE of 7-10¢/kWh
- Periodic fixes required

Matured Technology – 1995

- Optimized machines using best of current technology and recent results and analytical tools of the DOE Wind Energy Program
- COE of < 5¢/kWh
- Machines still designed for excellent wind sites

Advanced Technology – 2000

- New technology incorporating currently unexplored innovative concepts
- Broader markets/lesser wind sites
- Improve COE to < 4¢/kWh

P06-G0977510

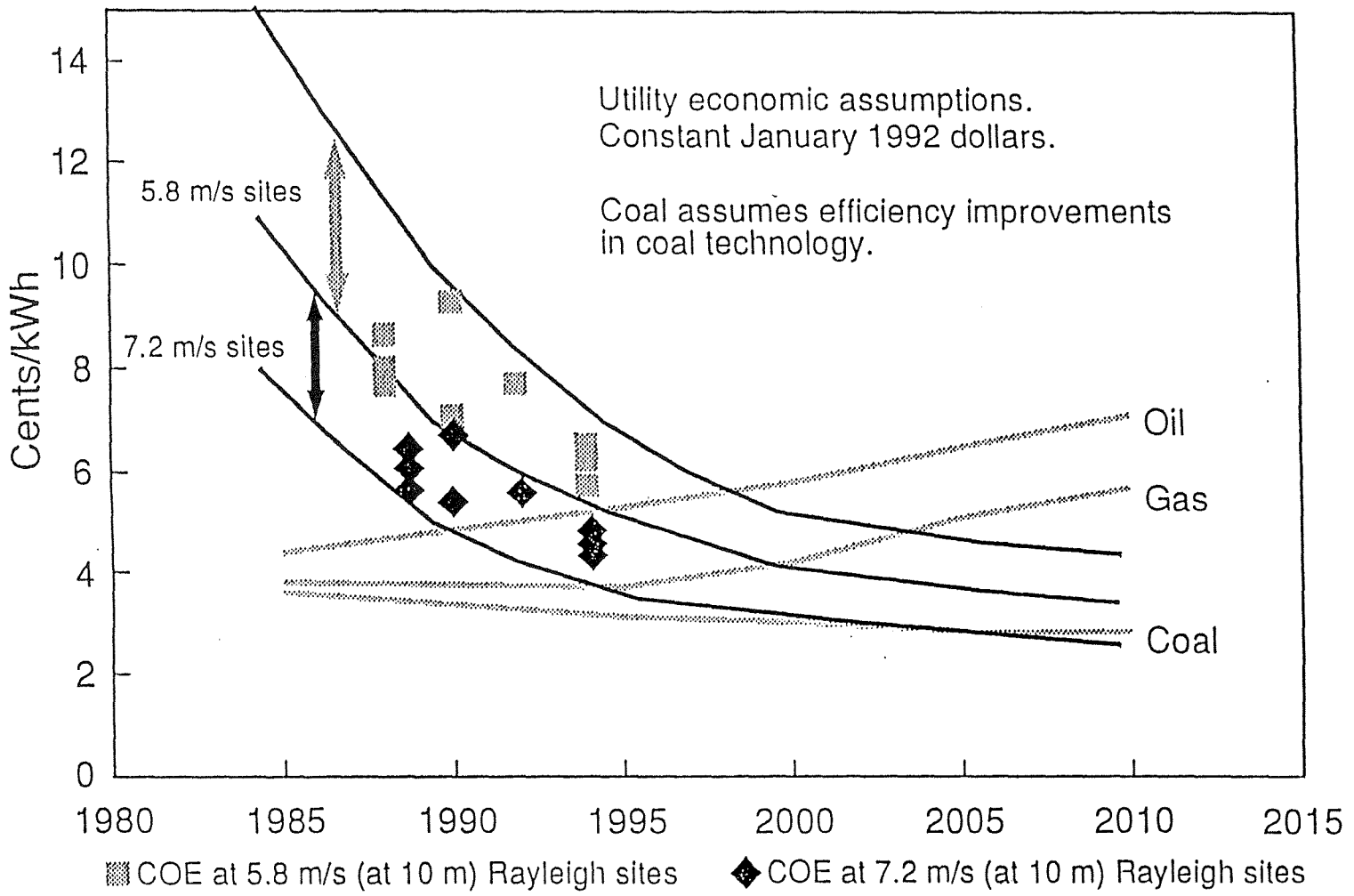
Levelized Cost of Electricity Is Calculated from Both Financial and Technical Performance Parameters

$$\text{Levelized COE (Constant Dollars)} = \frac{\text{Fixed Charge Rate x Initial Capital Cost}}{\text{Annual Energy}} + \frac{\text{Annual O\&M Expense}}{\text{Annual Energy}} + \frac{\text{Levelized Major Replacements/Overhauls}}{\text{Annual Energy}}$$

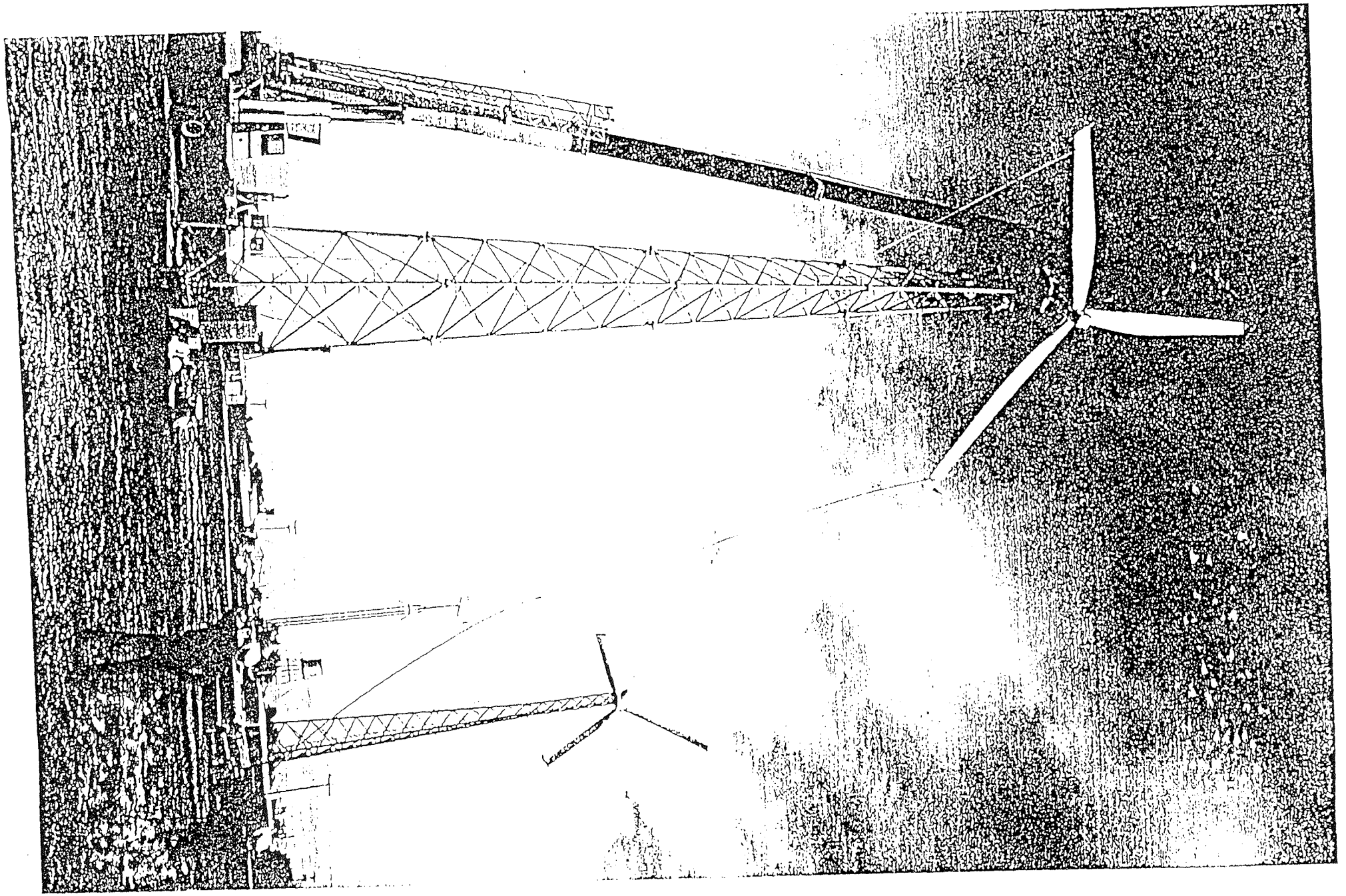
EPRI Tag Economic Assumptions

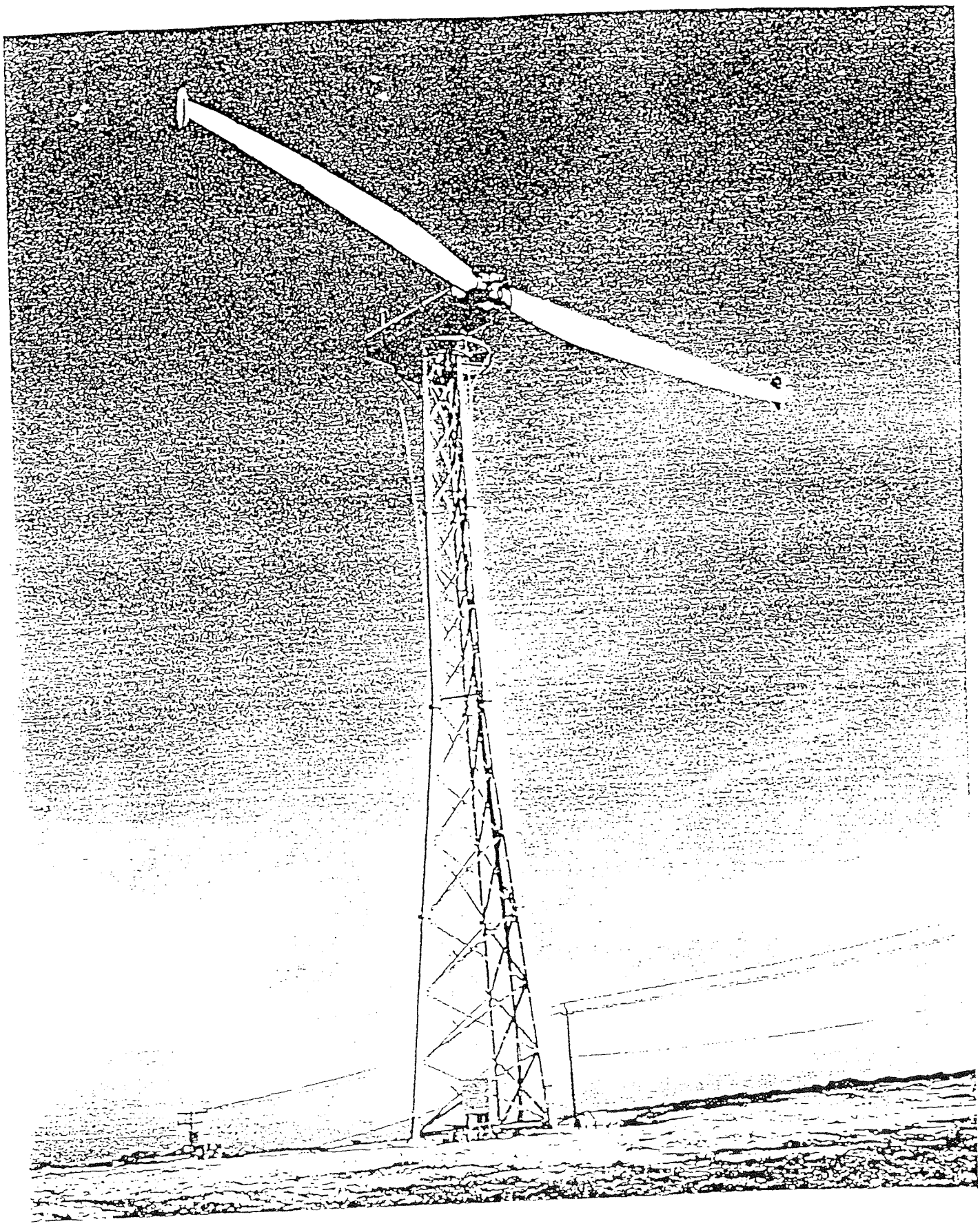
Discount rate	6.2%
Fixed charge rate	10.3%
Lifetime	30 years

COE Estimates for HAWTS



Source:"Technology Evolution for Wind Energy Technology (draft)", U.S. DOE, June 7, 1993

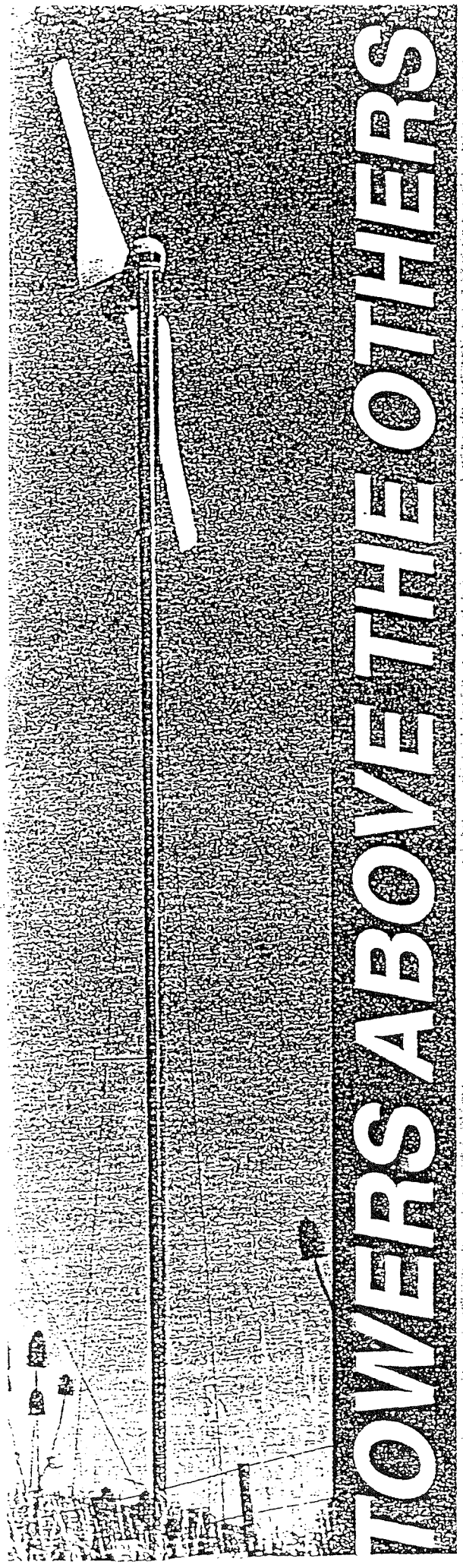




ADVANCED WIND TURBINES

The AWT-26

15042 NE 40th Street, Suite 204
Redmond, Washington 98052
(206) 867-0683 Fax: (206) 881-8468



- *In the May issue our claims for the Carter turbine are confirmed.*
- *Data from self-financed European wind farm.*
- *Independently verified power curve.*
- *Outstanding energy curve.*
- *Pricing policy achieves lowest cost per kwh.*

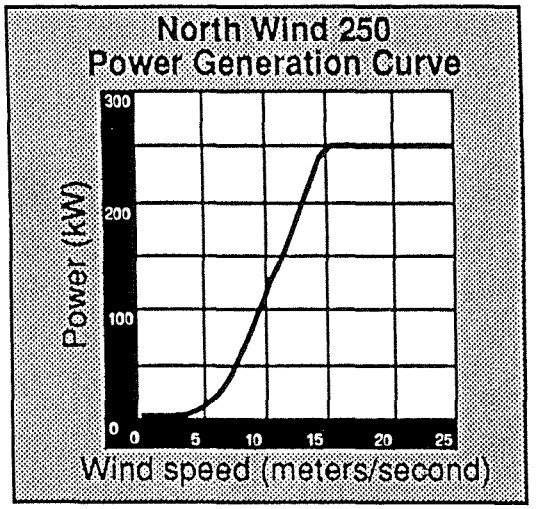
CARTER WIND TURBINES

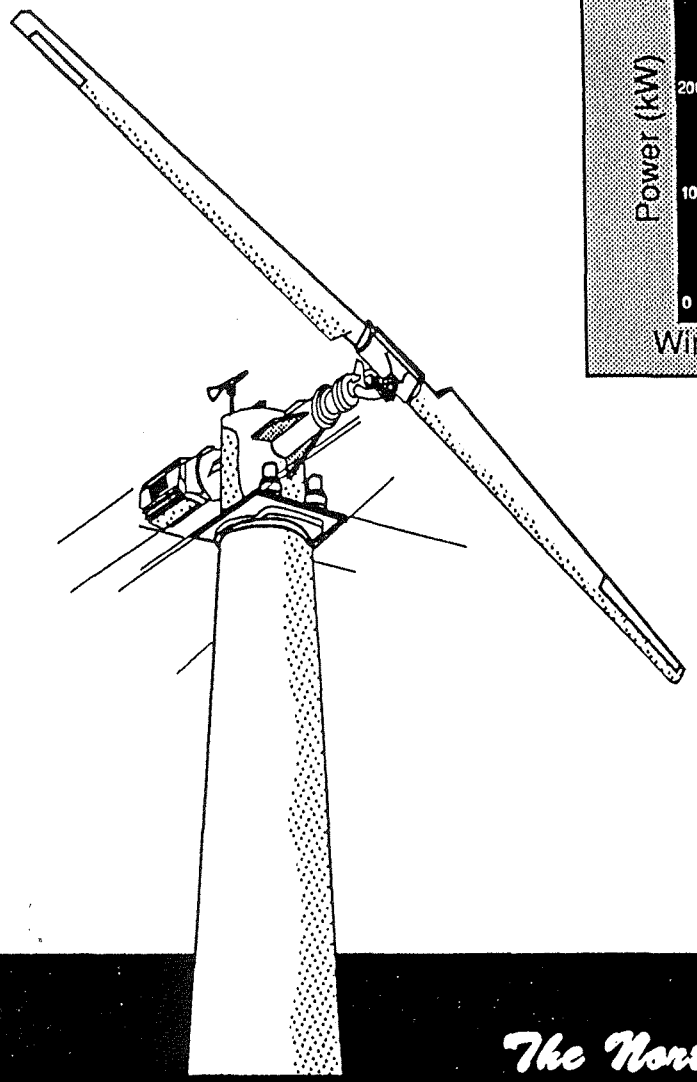
....for the generation to come

Carter Wind Turbines Inc
1900 FM 369 South Burkburnett, Texas 76354 U.S.A.
Tel (817) 569-3339 Fax (817) 569-1336

Carter Wind Turbines Ltd
Beaufort Suite, Lockington Hall, Lockington, Derby, DE74 2RH
Telephone: 0509 670500 Fax: 0509 670501

Northern Power Systems





The North Wind 250

North Wind 250
Technical Data

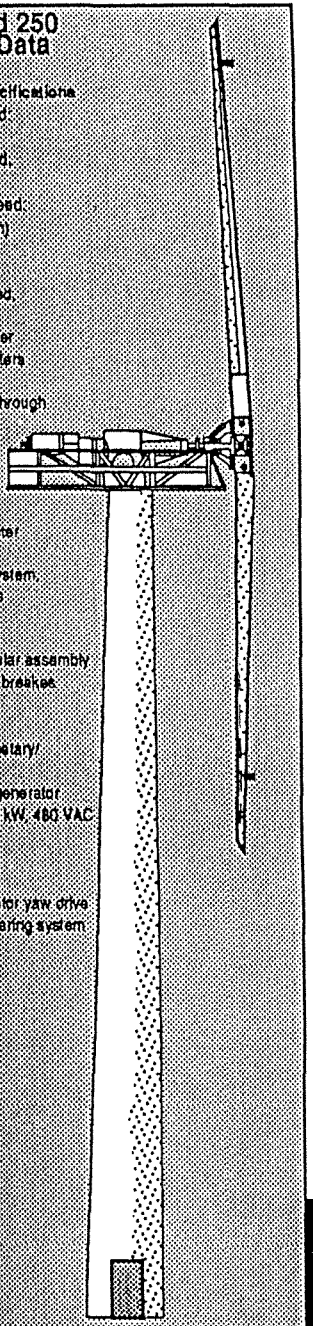
Performance Specifications
- Cut-in wind speed: 4m/s (9mph)
- Rated wind speed: 13m/s (29 mph)
- Survival wind speed: 54 m/s (120 mph)

Rotor
- Up-wind, 2-bladed, teetering rotor
- 25-meter diameter (490 square meters swept area)
- 2° coning, flow-through rotor structure
- 60 RPM
- Composit rotor construction
- Aileron controls
- Elastomeric teeter bearings
- Teeter control system, dampers breaks

Drive Train
- Integrated modular assembly
- Parking/service breaker

Transmission
- Proprietary planetary/ helical gearbox
- Asynchronous generator 1800 RPM, 250 kW, 480 VAC

YAW System
- Active sensor
- Electric gearmotor yaw drive
- Friction yaw bearing system



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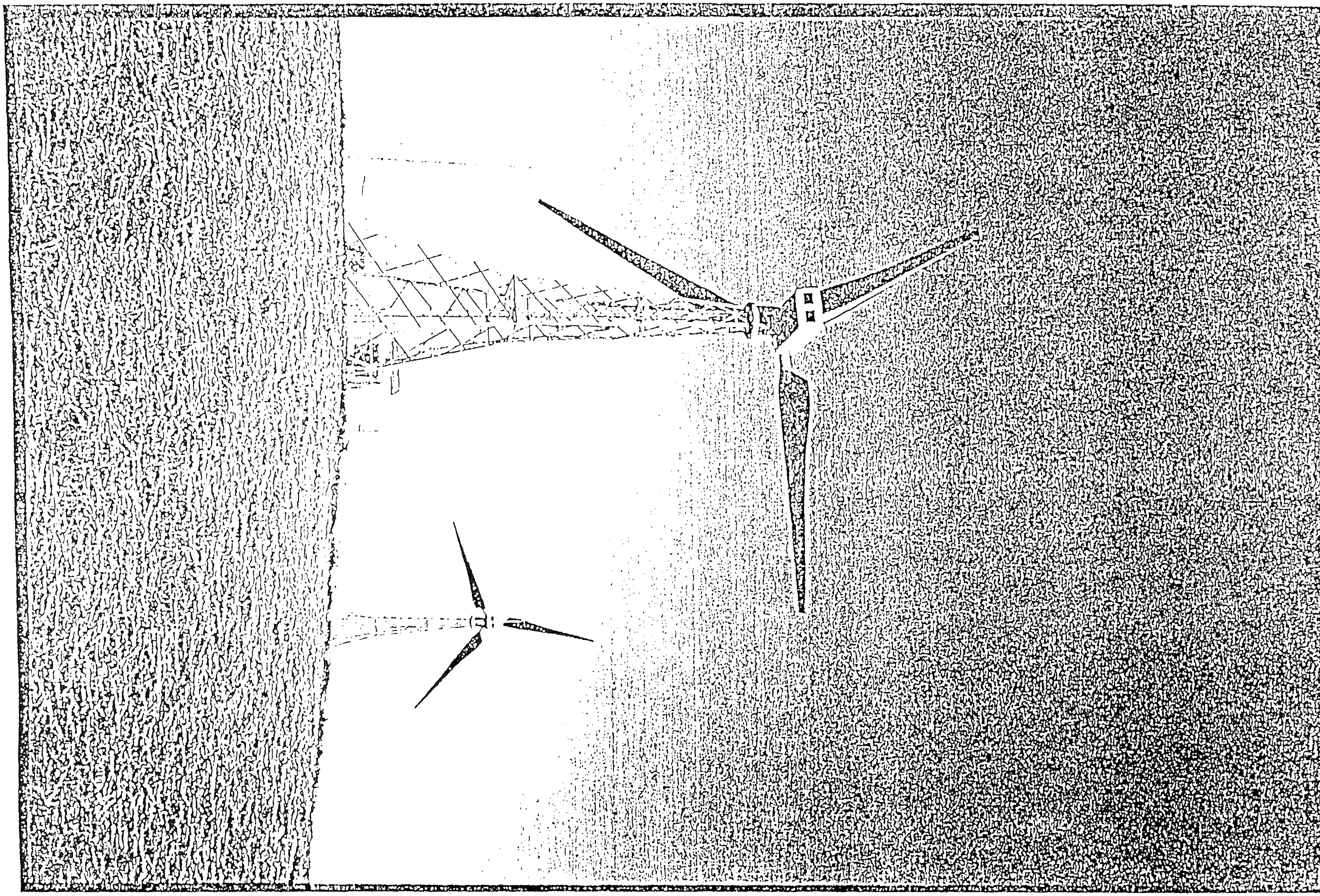
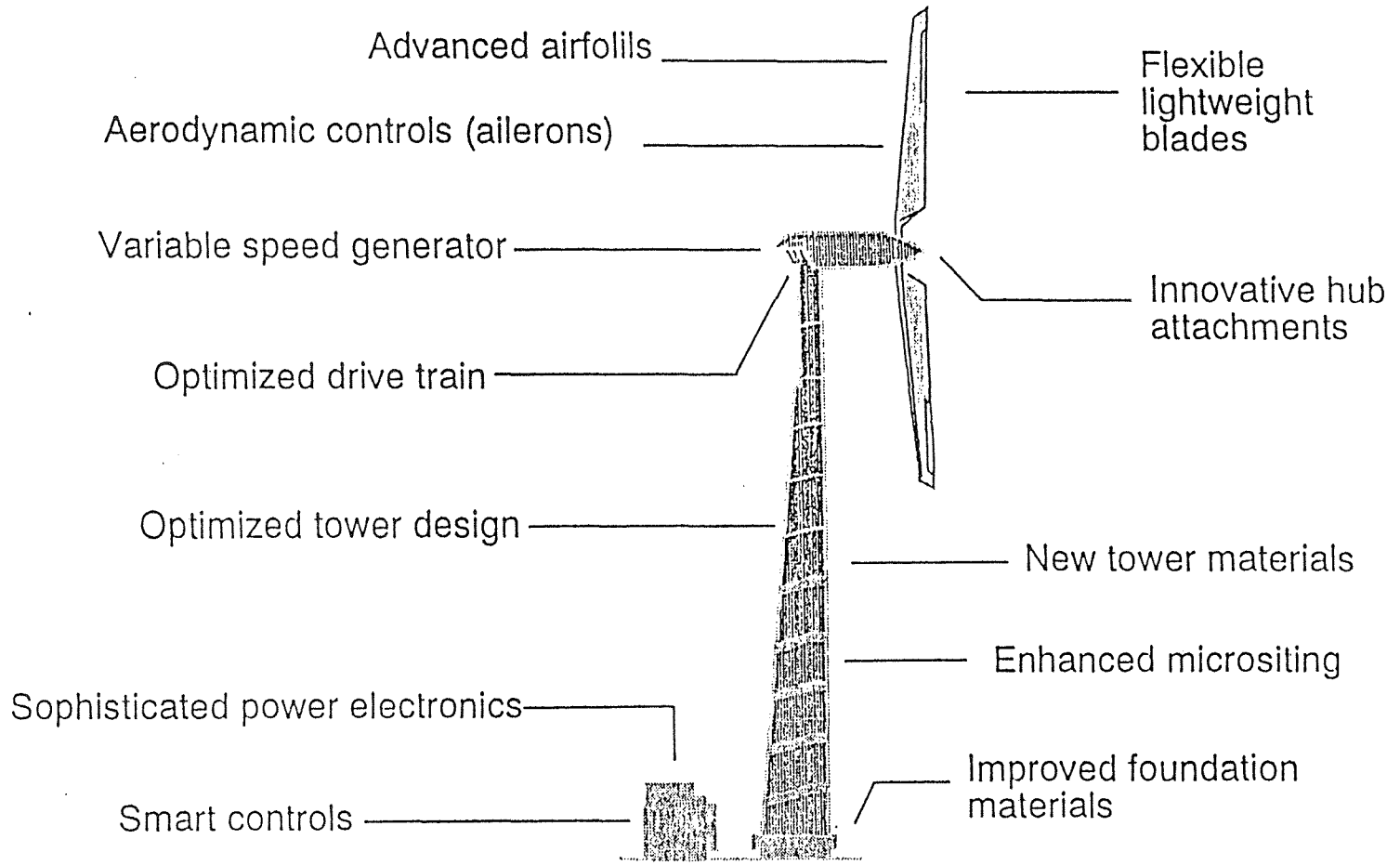


The Advanced Wind Turbine Concept

An artist's rendition of proposed turbine enhancements



P96-G0977519

NREL

Special Purpose Thin and Thick Airfoil Family

Thin Airfoil Family for Medium Blades

Tip region airfoil (95% radius)

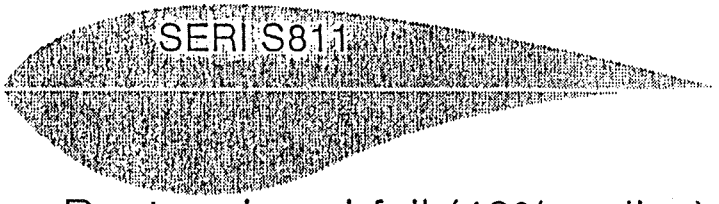
Primary outboard airfoil (75% radius)

Root region airfoil (40% radius)

Thick Airfoil Family for Large Blades

Tip region airfoil (95% radius)

Primary outboard airfoil (75% radius)



Root region airfoil (40% radius)

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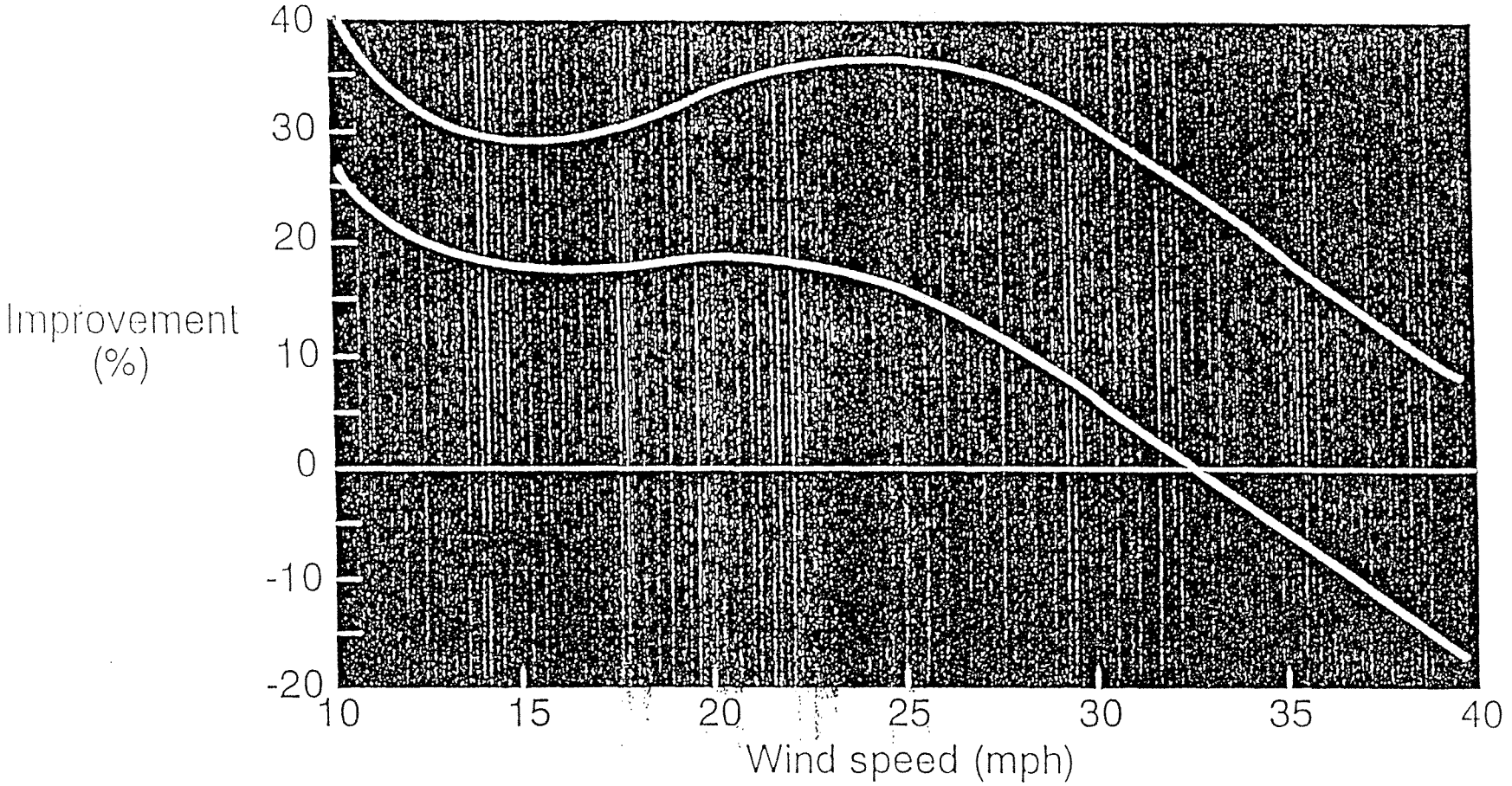
Generator Power Output Improvements (SERI Blade over Aerostar Blade)



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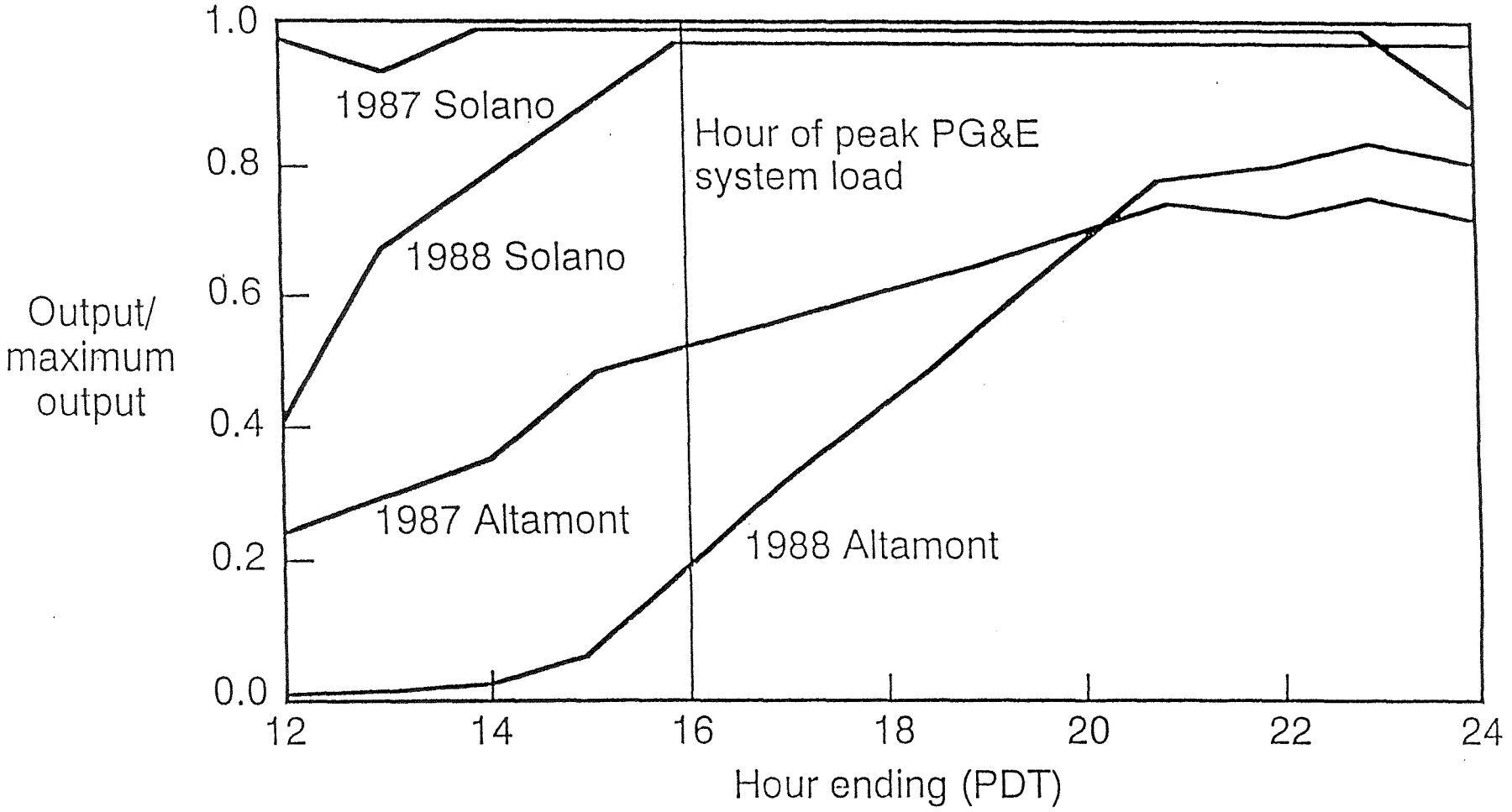
COEING
203 956

Wind Plant Output During PG&E Peak Load Days



P06-G0977513

Environmental Issues

- Avian mortality

  - CEC study between November 1984 and April 1988 showed 108 raptor deaths in Altamont and Tehachapi

    - 67% due to collisions with wind turbines
    - 33% due to electrocutions

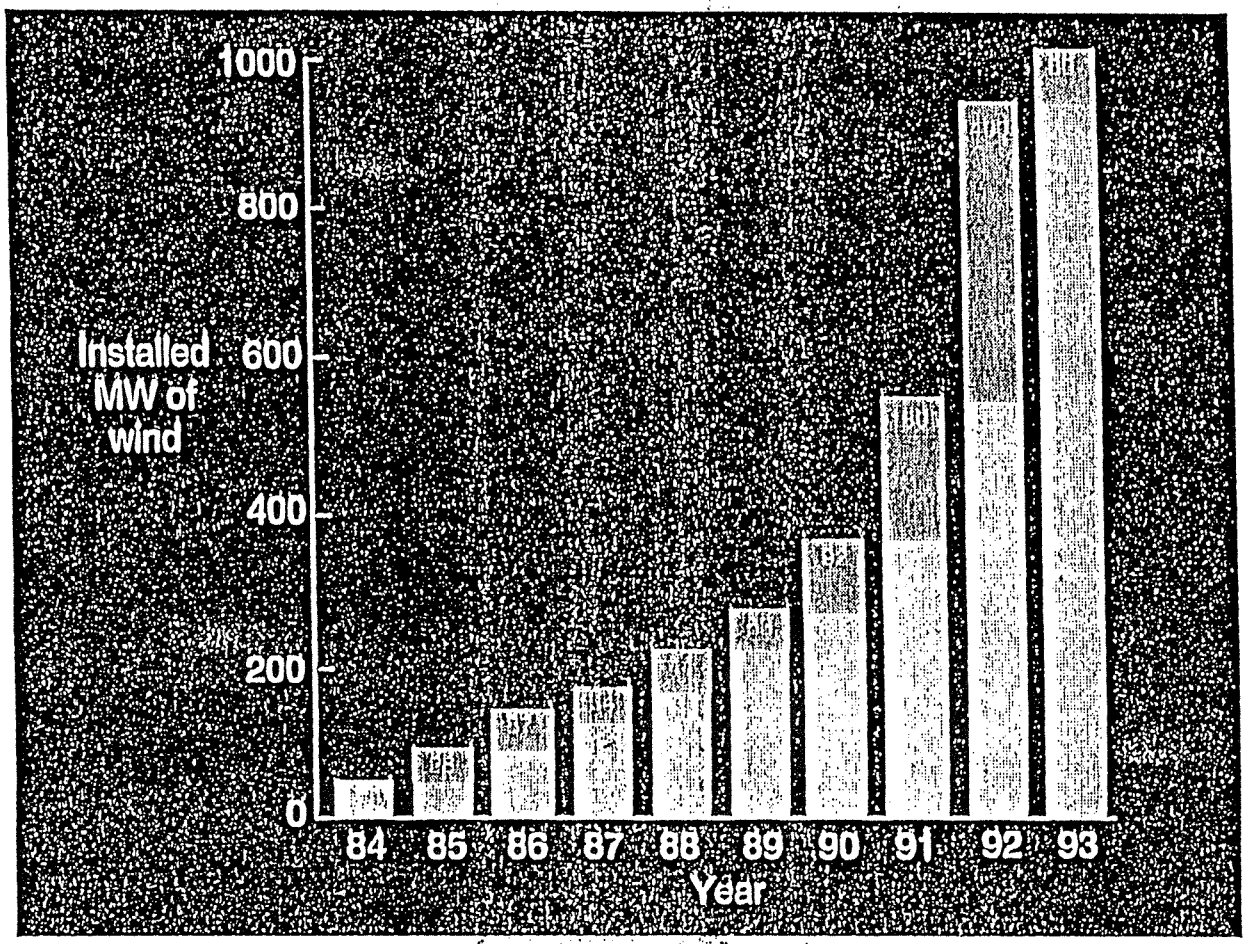
  - Bio Systems study in progress for Altamont and Solano areas

  - numerous avian studies being conducted in Europe

Environmental Issues (concluded)

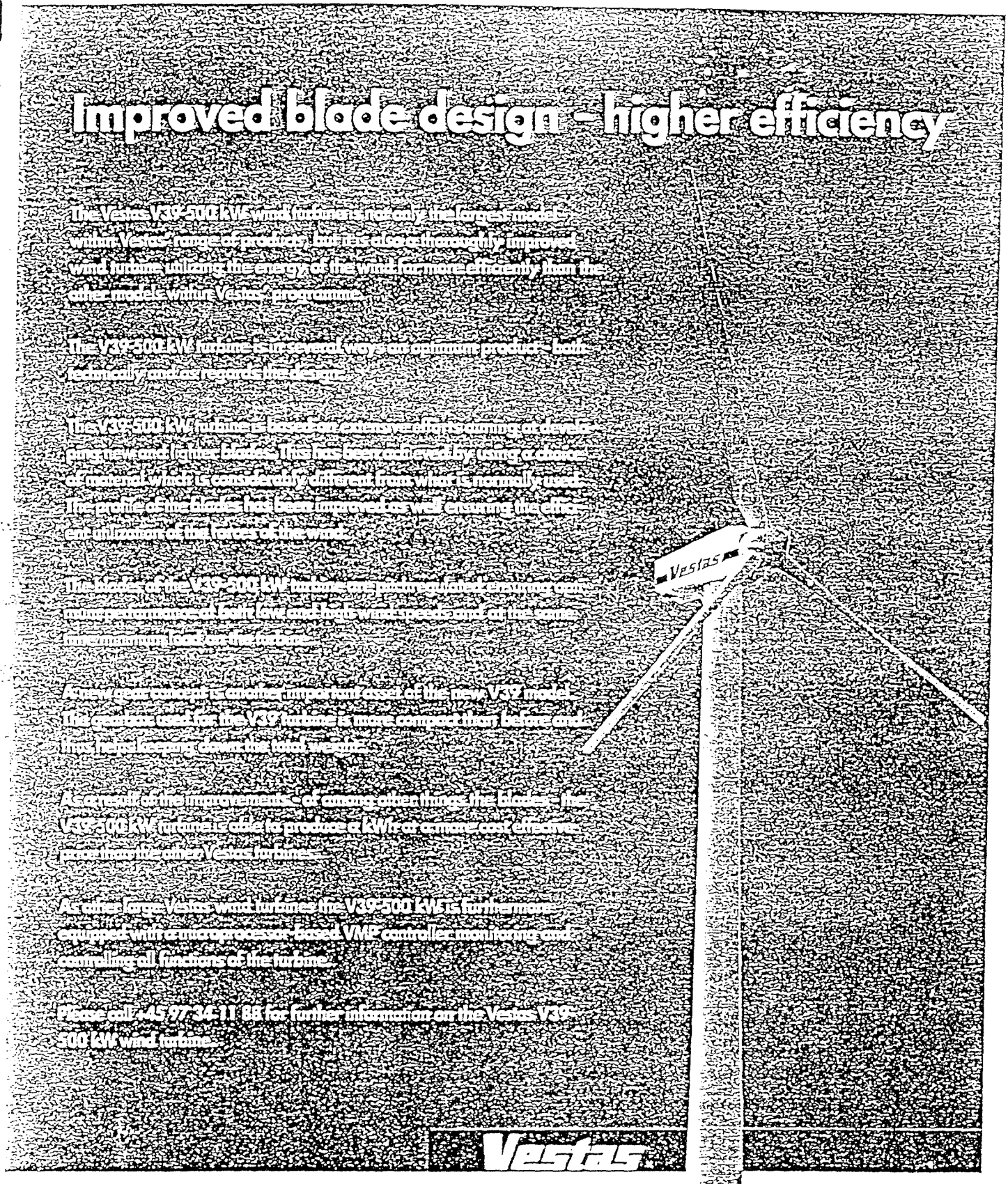
- Noise
  - requirements vary by county (i.e., 45 to 60 dBA)
  - more serious as population density increases
- Visual
  - requirements vary by county (i.e., viewshed analysis)

Installed Wind Capacity in Europe

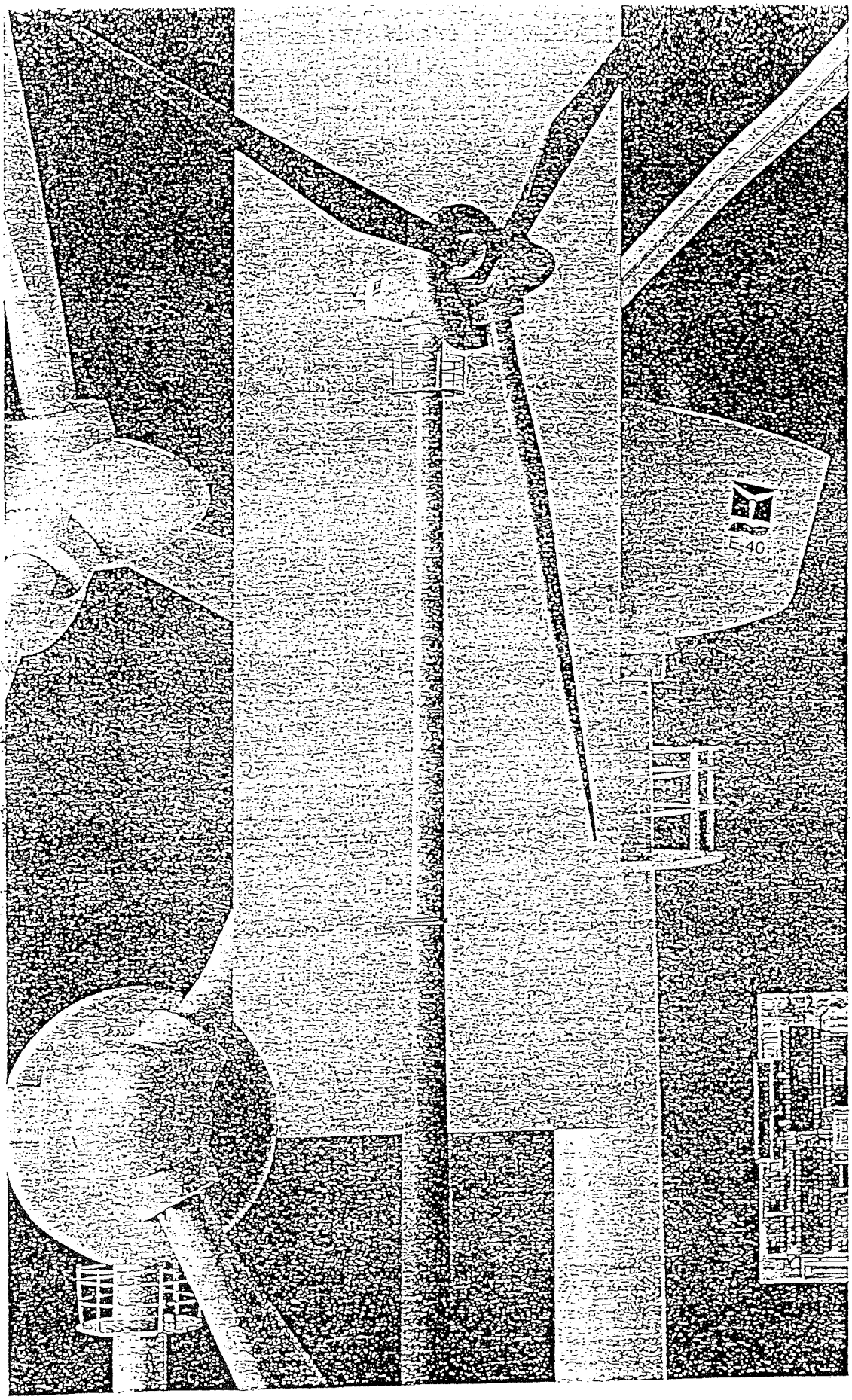


Reference source: Conference Reports by Windpower Monthly's Lyn Harrison, editor and Sara Knight, German correspondent

Improved blade design – higher efficiency



Vestas utilizes the natural forces of the wind. The manufacture of the Vestas wind turbines is based on years of experience. A carefully prepared and tested design is part of the qualities which have made Vestas the world's leading wind turbine manufacturer.



THE BEGINNING OF THE AGE OF WIND

ENERCON

Summary

Wind speed measurements at a proposed wind farm site will greatly improve energy capture estimates, and can be used to determine the capacity value of the energy.

There has been a significant improvement in wind turbine technical and economic performance over the past ten years:

Energy capture: 600 kWh/m² to 700 kWh/m²
Capacity factor: 17% to 23%
Cost of energy: $.10 - $.12/kWh to $.05 - $.07/kWh

Emerging design alternatives show the potential for continuing cost and performance improvements. New design options are under continuing development by the wind industry in the U.S. and Europe and should provide wind energy at $.05/kWh by about 1995.

Design and development of the next generation of wind turbines for the year 2000 is only now beginning. These new designs are expected to have a cost of energy of about $.04/kWh.

2.1.2 Panel Members:

Bob Gates–Zond Systems
Edan Harel–TRM Advanced Wind Technologies
Robert Lynette–R. Lynette and Associates
Jeff Maurer–The New World Power Company
Eric Miller–Kenetech Windpower

Panel Responses:

Bob Gates – Zond Systems

The perception that the wind industry requires government subsidies is incorrect. One half of the wind industry has been developed since tax credits expired in the early 1980s.

The goal that the industry set for a 5¢ /kWh by 1995 has been achieved. Proposals and bid solicitations are currently citing 5¢ /kWh for projects that will be coming on-line in the next year or so.

The cash cost per kWh for projects of independent power producers is higher than for utility ownership models because of inequity in the allocation of risks to the independents who sell their power to the utility. Utilities pay for the electricity delivered leaving all of the risk costs (legal infrastructure, technology risks, workmen compensation, etc.) to be borne by the independent power producers. Thus, some of that risk cost must be borne into the cost capital from an equity standpoint.

The increased costs per kWh for the independent developer who bears all of the risk costs is balanced by the fact that while costing less per kWh in capital costs, in the utility ownership model, all of the risks are borne by the rate payer.

The federal government's role in pushing wind turbine technology forward has been meaningful, according to Mr. Gates, especially in the case of advanced airfoil designs. He agreed that the industry is headed toward newer, larger turbine models of 500 kW or more. By increasing the size of the turbines, developers are able to lower their costs. The turbines are more efficient, thus fewer turbines are needed.

He emphasized the importance of maintaining a proper perspective on the avian issue. If one hundred bird deaths occur as a result of wind turbines, we must evaluate them in the context of the impact on the population of the birds overall or consider the alternative impact. What if we burn coal instead? What then is the impact on birds as well as other living things on earth?

Edan Harel – TRM Advanced Wind Technologies

Mr. Harel introduced himself as an international representative of the wind industry. In Israel, where he owns and operates a 6 MW wind farm installed with 600 kW wind turbines, Mr. Harel sells electricity for less than 5¢/ kWh. He emphasized that this was achievable without the need of government subsidy.

"I can tell you that the future is here and now," he said naming some of the criteria used in the manufacturing community when information is exchanged. Manufacturers strive to maintain standards set by the industry as closely as possible. Currently, there is a common understanding that *big is good* (i.e., 500 kW, 600 kW, 700 kW). Manufacturers are developing wind turbines with simpler designs and smart solutions to old problems such as the idea of moving to an operational regime of less loads and constant control of loads. Material engineering is much improved, however, power quality is still a problem.

Utilities and developers must keep in mind that the final product is not a machine or the services of the utility but a cooperative partnership, he said.

Jeff Maurer – New World Power

Mr. Maurer began by stating that the price of oil will go up in the not too distant future. For that reason in Hawaii, with its abundance of wind resources, it is imperative to act now with wind power.

He observed that the reason California developed wind power so effectively was because of the government subsidies and the purchase power contracts. "We had a lot of successes and a lot of failures, but we learned a lot."

Three billion kilowatts of wind power are produced in California annually representing three quarters of the total world production of electricity from wind power, enough to power the city of San Francisco, he said.

Problems with wind power include the lack of firm capacity power which can be successfully counteracted with hybrid systems. Micrositing[1] is another solution, he noted. "If your wind resource peaks at night and your power demand peaks during the day, micrositing turbines will allow you to match the peak with maximum generation of power."

[1]Editor's note: For example, siting the turbine in a wind regime that matches the utility load better.

Mr. Maurer believed the workshop to be a necessary step toward implementing wind power by enabling the participants to learn from each other in order to go forward with a plan to implement wind power in Hawaii.

"Wind is a solution for the long term energy needs in Hawaii," he said in closing.

Robert Lynette – R. Lynette and Associates

Mr. Lynette began by pointing out the strong resurgence in the interest in wind energy going on in the past few years.

"The dynamics of what's going on this time in the early 1990s is not based on the tax incentives and the government subsidies of the early 1980s," he noted. This time there is strong public support, strong government support, and strong support from the Electric Power Research Institute (EPRI).

Predicting a low cost of 3½¢/kWh for wind power within the next few years, Mr. Lynette stated that the price decrease will be due to three notable factors:

- the forming of new alliances with large players in big industry,
- technology innovations will lower costs 15% - 20%, and
- increased growth will allow the industry to produce decent quantities.

Given the current 1½% - 2% U.S. growth rate in electricity demand, if wind captures 10% of that growth (10% of 2%), that will result in a $5 billion a year industry. This is the major attraction for big industry.

With the involvement of big players, the wind industry will be able to do away with one of the principle fears utilities have, that of increased risks. Alliances with big industry will add solidity to the wind industry.

"I think within the next year or two you will see a very different look to the industry," he said in closing.

Eric Miller – Kenetech Windpower

The wind industry has moved out of California and into the global market. Wind energy is now fully competitive with fossil fuels. In the bidding process in California, renewables either won or came very closing to winning over fossil fuels in head to head competition, Mr. Miller said.

As an example of how technology has helped to bring costs down, Mr. Miller pointed out that variable speed drive technology has made a big difference in load control.

For Hawaii, one of the key elements which ought to be considered in moving wind energy forward is how power additions are acquired. That is, how do wind and fossil fuels compete politically and economically. When it comes to comparing resources, Mr. Miller deduced, it will come down to a question of values. Since wind is not dependent on fuel cost fluctuations and thus insulated from those risks, the value of wind power to price stability is less of a risk, he said.

"There is no question that the lowest cost, long term resource in Hawaii is wind," Mr. Miller said in closing. "The question is what is the framework to make it possible to capture those benefits here in Hawaii."

Question:

What are some of the installation costs of wind power?

Answer:

Bob Gates – Zond Systems

Installation costs vary depending as much on the project size as anything else including risk factors but a general overall estimate is about $1,000 per kW.

Sue Hock – NREL

While you can have a less expensive installation and higher O&M costs, you may not do as well with a more expensive installation that operates more efficiently. For this reason, a better measure of installation costs may be the cost of energy rather than the cost per kW.

Jeff Maurer – New World Power

Installation costs should not be considered as much as financing costs. The amount of cash flow you will have **after** you have financed the project if you can get low financing for your project, will make a great difference.

Edan Harel – TRM Advanced Wind Technologies

A good criteria for keeping installation costs down is to consider the amount of kWhs that can be produced annually per turbine. By upgrading his 36 m diameter blades to 45 m diameter blades on his turbines while still maintaining

them as 600 kW turbines, Mr. Harel was able to produce many more kWh per year and drive the cost per kWh down to capture more energy for the same cost.

Question:

Are developers and utilities able to negotiate a contract with higher up front costs?

Answer:

Bob Gates – Zond Systems

Mr. Gates used the United Kingdom to illustrate how power contracts are negotiated with higher capital costs paid out during the early years of the project to reduce debt and the resulting debt load quickly. These types of contracts, much like comparing a 15 year mortgage loan to a 30 year one, result in a much lower total price paid out over the life of the project while maintaining lower O&M costs, a recognition of better overall economic efficiency.

Jeff Maurer – New World Power

Domestically, New World Power is responding to many utility RFPs on a price per kWh basis, and the bidding process is very competitive.

Eric Miller – Kenetech Windpower

A cost-effective contract for wind is one that is well matched to the higher capital costs over the long term. One of the great advantages of the wind technology is that ability to lock in at a fixed price over the long term, a key element common among all successful wind development projects.

Bob Gates –Zond Systems

The primary benefit of wind power to the utility or the power rate payer, is its hedge against future fuel costs and taxes. While fossil fuel costs are going up, wind prices will be going down.

Question:

In Hawaii where projects are built on a much smaller scale than on the mainland, what kind of help in terms of government assistance should be expected?

Answer:

Bob Gates – Zond Systems

In clarifying a statement made earlier in which he said government support was no longer needed, Mr. Gates emphasized that he was speaking in terms of tax credits and the government subsidies of the early 1980's. The government still plays a significant role in the renewable energy industry, particularly wind, he said.

One key role that government plays is by providing a stable regulatory environment. By ensuring a highly secure and reliable regulatory environment in which independent utility operators can operate, the risk premium charged by the financial community is lower, he said.

One area that Mr. Gates felt may be appropriate for government to look into, which is missing in today's regulatory environment, is an investment requirement to incentivize utilities to deal with the independent developers.

Edan Harel – TRM Advanced Wind Technologies

It is time for the wind industry to forget about the direct government subsidies of the past which were not economically effective, Mr. Harel said. Today's state of the art technology allows for the direct pricing of projects to be economical.

Jeff Maurer – New World Power

Government can help by providing a level playing field for wind developers to play on, Mr. Maurer stated. Currently, a utility is only required to buy power and thus avoid its risk costs.

Sue Hock – NREL

Ms. Hock said that she has been involved in discussions with several utilities that are reluctant to invest in wind power given its high risk environment. By reducing the up-front cost of technology to get the market rolling, government can play a significant role in supporting wind development, she said.